DIRECT-TO-EARTH RADIO LINK FROM THE EXOMARS SCHIAPARELLI LANDER
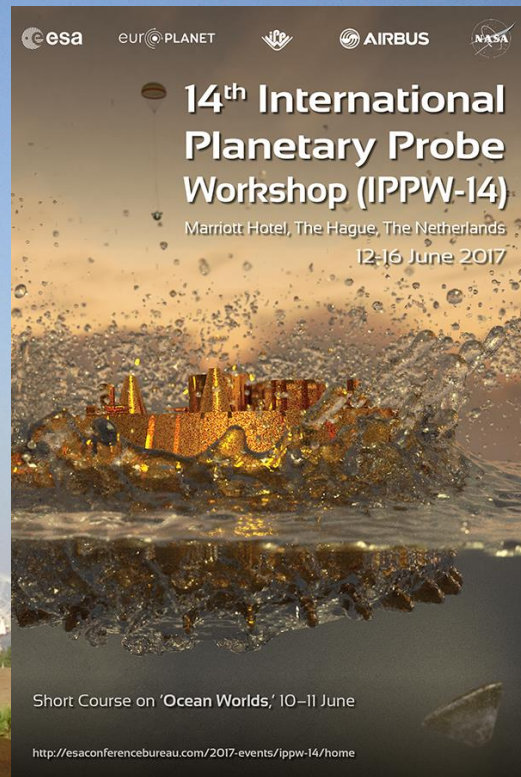
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Motivation

- **ESA's ExoMars Trace Gas Orbiter released Schiaparelli last October**

- **Giant Metrewave Radio Telescope recorded UHF signal during EDL**

- **Made available the only near real-time visibility of status at mission operations center**

- **During latter stage of sequence, anomaly resulted in loss of the lander, which was first observed and reported via the loss of the UHF signal at GMRT**

Accomplishment

- **Data acquired in Direct-to-Earth effort useful for reconstructing events, especially when combined with carrier signal received by TGO, Mars Express, and telemetry from on-board sensors**

- **Understanding the probe's state and trajectory**

- **Contribute understanding Mars's atmosphere in cooperation with the Atmospheric Mars Entry and Landing Investigations & Analysis (AMELIA) team. AMELIA aims include studying the major properties of Martian atmosphere, such as density, pressure, temperature and wind**

GMRT

- GMRT is an array of thirty 45-m antennas operated by the National Centre for Radio Astrophysics

- A sub-array of 12 of the antennas was utilized during EDL event, an effective collecting area equivalent to a single 156-m diameter antenna

- For separation, 16 antennas were utilized

- Signal level too low to recover Schiaparelli data stream

- Objective was by design detecting the lander's residual carrier signal, which was predicted to be just a few dB above noise floor
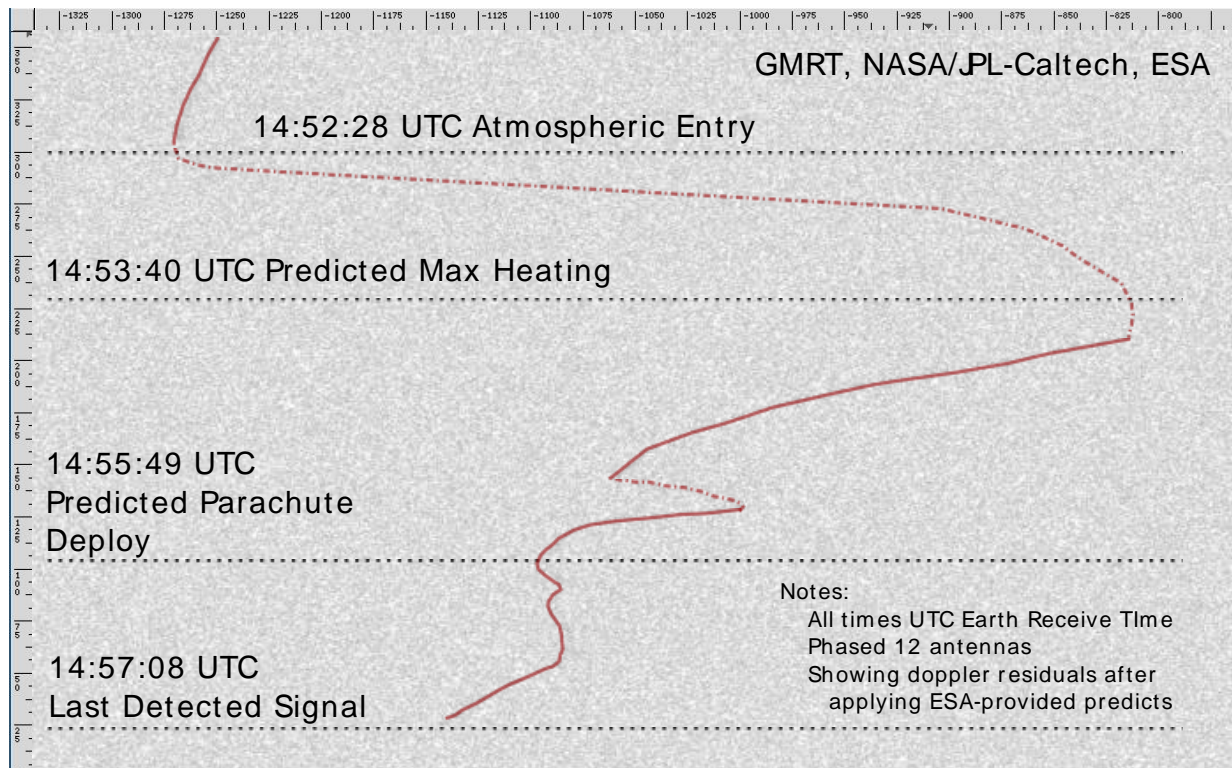
ExoMars/Schiaparelli/EDM Entry, Descent, Landing (EDL) Detection at GMRT, India 2016-10-19

Spectrogram Frequency (Hz) vs. Time (s)

GMRT, NASA/JPL-Caltech, ESA

14:52:28 UTC Atmospheric Entry

14:53:40 UTC Predicted Max Heating

14:55:49 UTC
Predicted Parachute
Deploy

14:57:08 UTC
Last Detected Signal

Notes:
All times UTC Earth Receive Time
Phased 12 antennas
Showing doppler residuals after
applying ESA-provided predicts

14:57:50 : Predicted Backshell & Parachute Jetison
(This exposes + 6 dBiC antenna), Thrusters On
14:58:20 : Predicted Thursters Off & Touchdown

- Figure shows the observed Schiaparelli carrier frequency, after removal of an a priori model based on the predicted lander trajectory. This information was made available via Internet from GMRT to ESOC during the landing event. The GMRT analysis provided confirmation of the aliveness of the lander through entry, peak heating, and subsequent parachute deployment. At 14:57:08 UTC Earth Receive Time, the signal was unexpectedly lost. This epoch corresponds to a Spacecraft Event Time (SCET) of 14:47:21, well in advance of the predicted touchdown time of 14:48:33
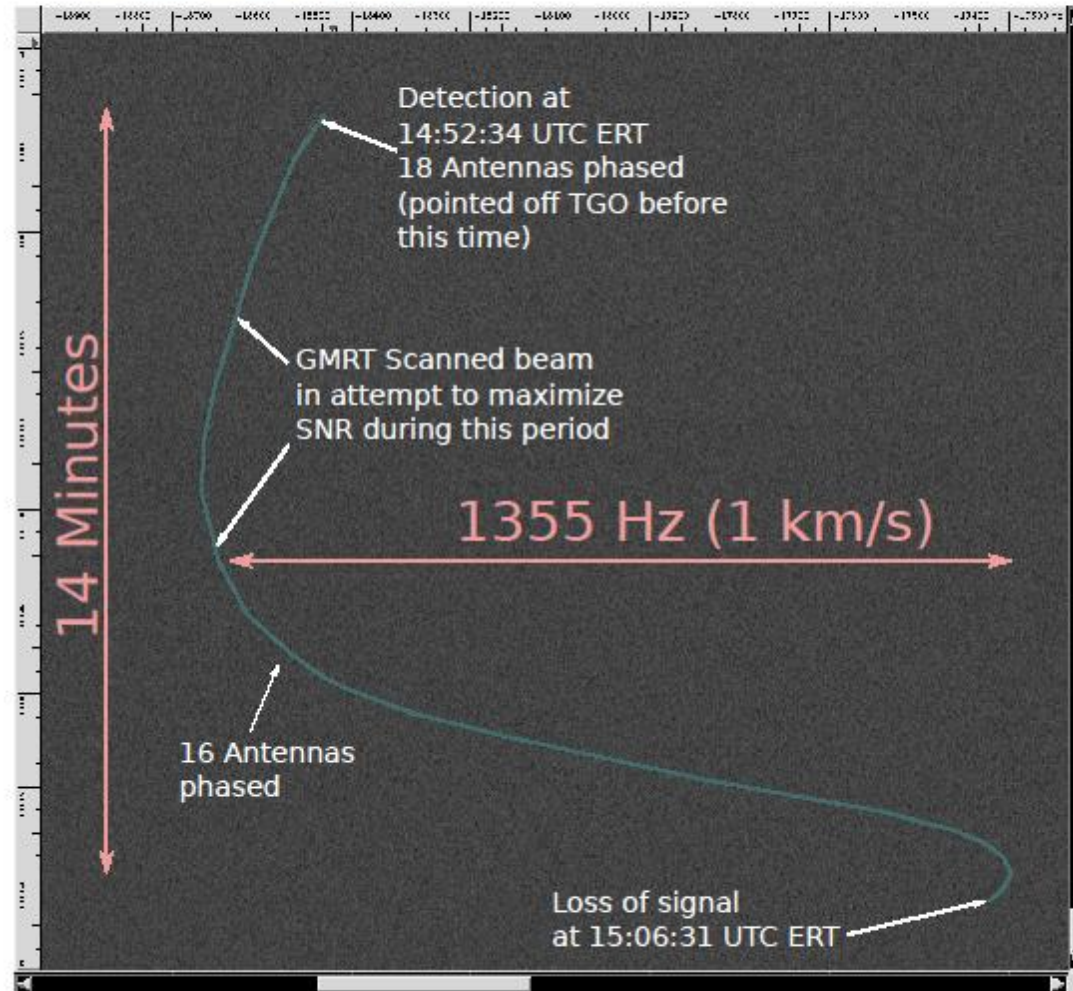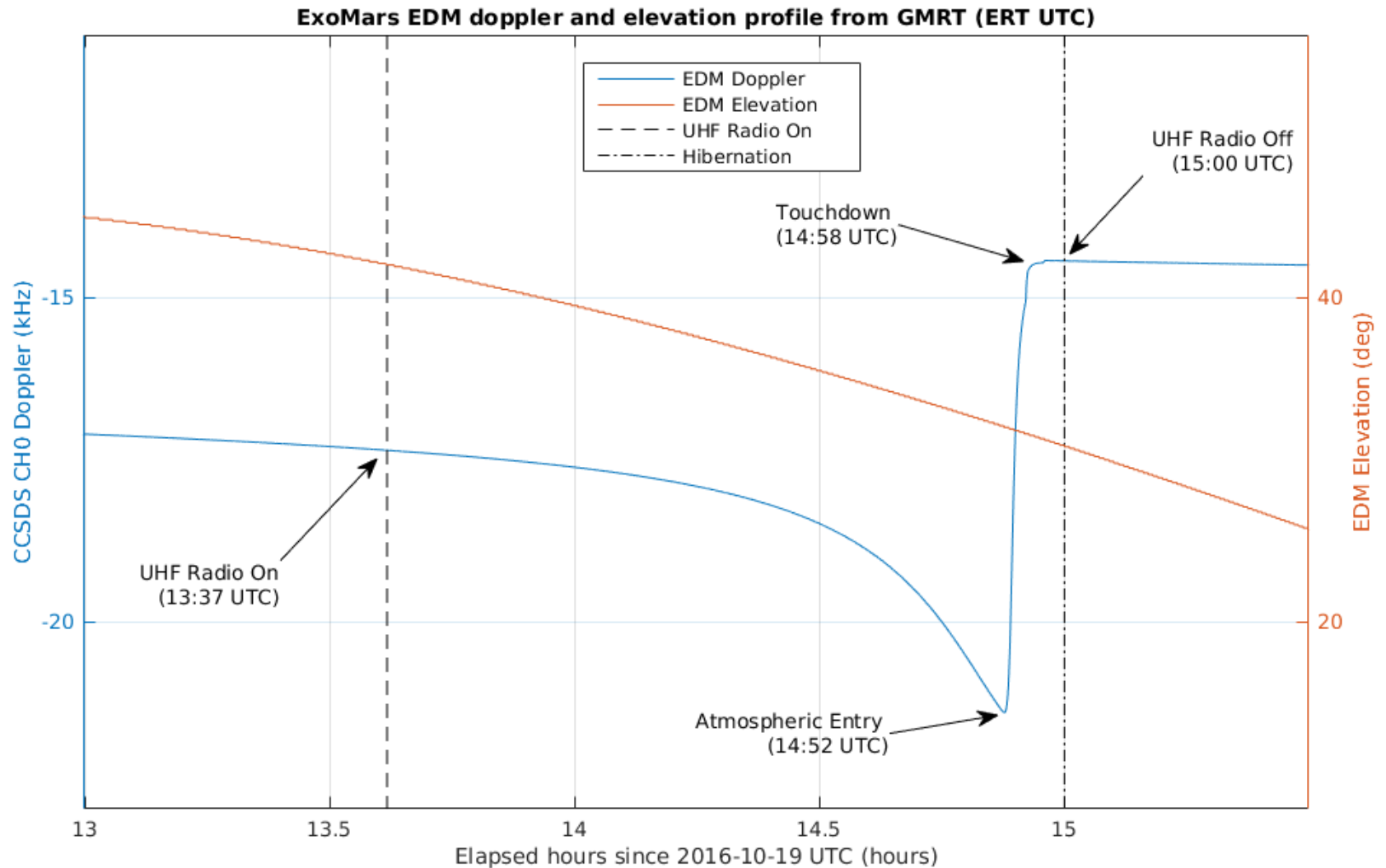
TGO/EDM Separation Event
UHF Detected at GMRT, India
2016-10-16

GMRT/NASA-JPL/ESA

GMRT Doppler & Elevation Profiles

ExoMars EDM doppler and elevation profile from GMRT (ERT UTC)

UHF DTE Link Performance

- **Initially assume 25 dishes for link analysis:**

  - **Effective Area: 19,880 m² (25 dishes, 45m, 50% efficiency)**

  - **Expected Pc/No: 17.2 dB-Hz (+6 dBiC) to 1.3 dB-Hz (-10 dBiC)**

    - **Depending on EDM antenna pattern**

- **Spacecraft-Earth range at arrival ~ 1.16 AU**

- **Frequency = 401.585 MHz; transmitted power = 5 W**

- **System Temperature = 106K (Mars ~10 degrees off galactic plane)**

- **Target sensitivity at GMRT ~3 dB-Hz**

- **An orbiter overhead receives UHF signal from lander**
- **Relays telemetry to DSN**
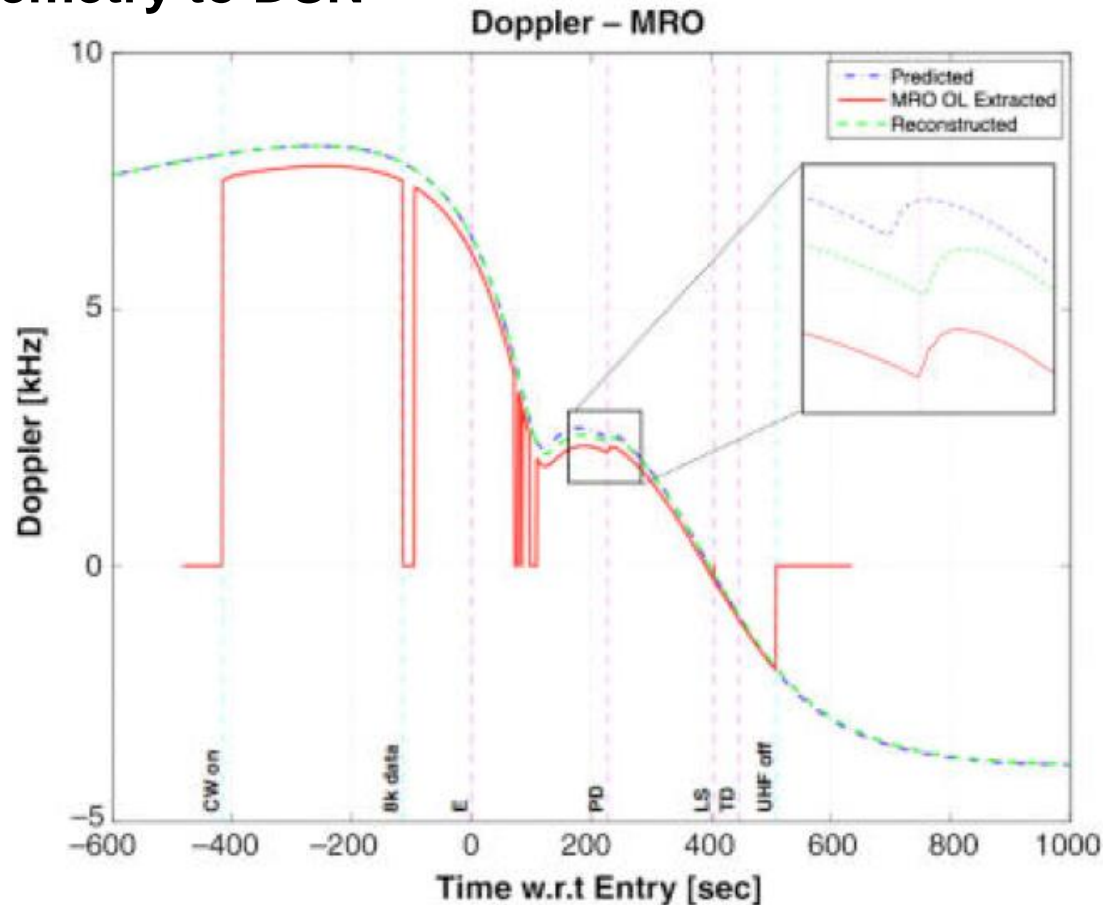
Figure 2. The Doppler profile of the EDL sequence of the Phoenix mission as captured and relayed through the MRO spacecraft in 2008.
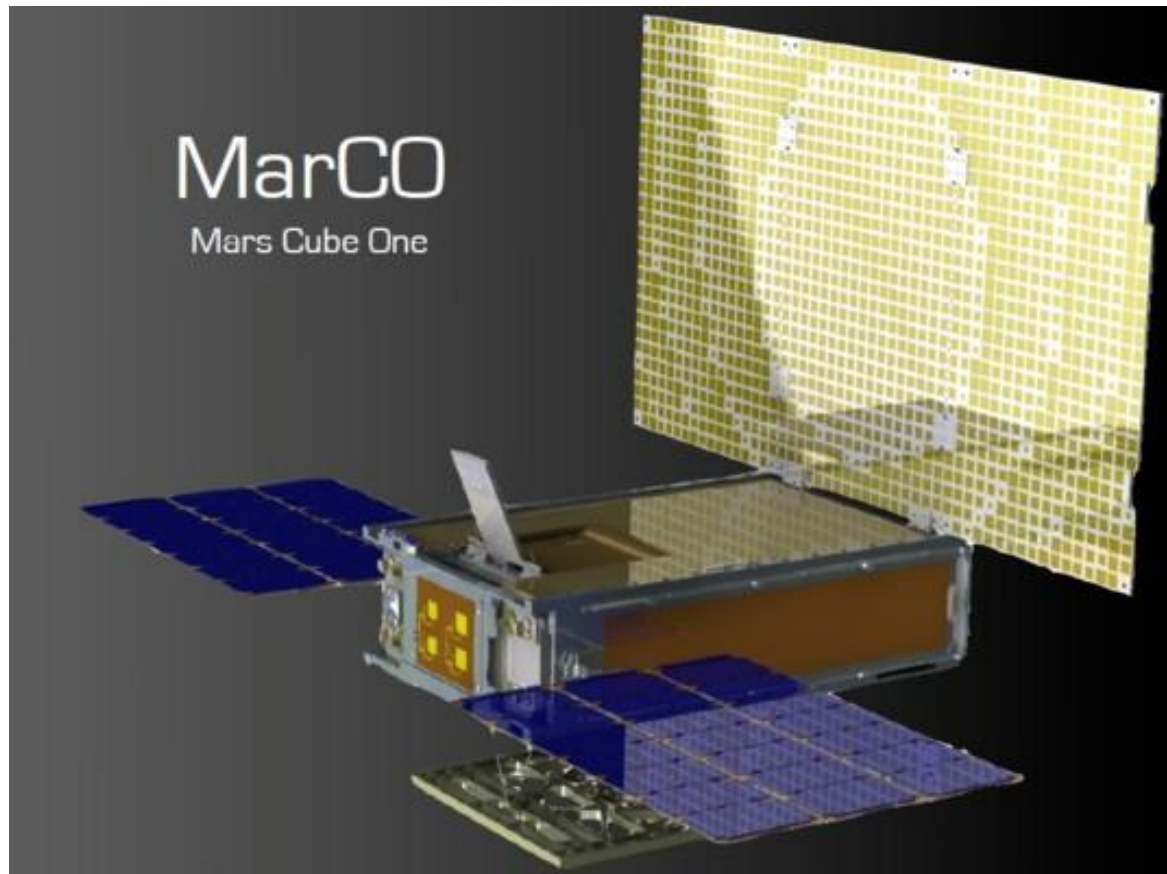
- **In the absence of sufficient link budget for telemetry, the Doppler profile received at Earth reveals very important information**

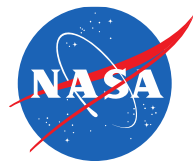- **Curiosity UHF Doppler profile received at Parkes Radio Telescope in 2012**
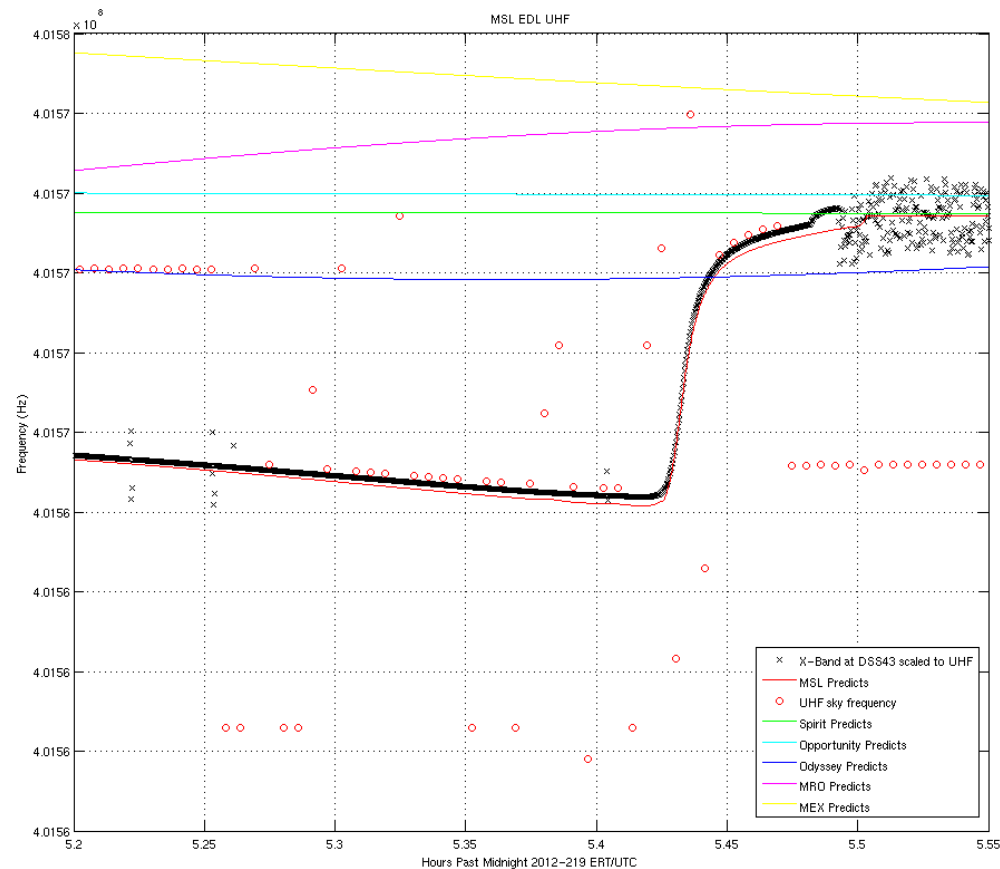
Introducing MarCO

- **CubeSats have not flown in deep space yet**

- **Fly CubeSat with the mission to watch EDL event and relay data to DSN**

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